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"Tom and Pepper Lab". Robotics for cognitive stimulation and social skills: A preliminary study

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ABSTRACT

Dementia affects over 55 million people globally, with early cognitive decline, such as Mild Cognitive Impairment (MCI), often preceding neurodegenerative diseases. This decline impairs memory, attention, and Theory of Mind (ToM). Early intervention is crucial, and assistive robotics has emerged as a promising non-pharmacological approach in this regard. This preliminary study evaluated the acceptability of the social robot Pepper and tested the structured cognitive and socio-cognitive training delivered by the robot. Nine participants, aged 68–93, ranging from mild to moderate dementia, were engaged in a four-week training program. A qualitative analysis of the interviews and video recordings of the training sessions was conducted. Results showed high participant engagement, increased autonomy and focus, and positive emotional responses. These data are promising in demonstrating structured training implemented in social robots has the potential to positively impact cognitive function and emotional well-being through structured training.

1. General introduction

Dementia currently affects over 55 million people globally, with most cases occurring in low- and middle-income countries. Approximately 10 million new cases are reported annually, making dementia the seventh leading cause of mortality and a major source of disability among the elderly (World Health Organization, 2023). Early forms of cognitive decline, such as Mild Cognitive Impairment (MCI), often precede Alzheimer's and Parkinson's diseases, impacting memory, attention, language, and executive function (American Psychiatric Association, 2013; Castelli et al., 2016; Saredakis et al., 2019). MCI also affects Theory of Mind (ToM), i.e., the ability to understand one's own and others' mental states (Premack, Woodruff, 1978), which may worsen with age and cognitive decline (Knopman et al., 2014; Moreau et al., 2015; Rossetto et al., 2020; Winblad et al., 2004). Early intervention in neurodegenerative conditions is critical to preserving cognitive function, and assistive robotic interventions have emerged as a promising non-pharmacological approach to cognitive and social training in recent years (Heitmueller et al., 2014; Knopman et al., 2014; Marchetti et al., 2018, 2022; Wenisch et al., 2007). However, despite scientific interest, interventions remain inconsistent and lack structured protocols (Figliano et al., 2023)

1.1. Preliminary study aims

The present study was conducted as part of a research project that will explore the feasibility of cognitive and socio-cognitive training programs mediated by the social robot Pepper. The main objective is to address the current lack of systematic approaches in training programs for elderly individuals using social robots (Figliano et al., 2023). To this end, this preliminary study aims to evaluate the acceptability of the social robot Pepper and to test the feasibility of the training. Additionally, the impact of the robot on the therapeutic relationship was observed, thus paving the way for a more comprehensive study aimed at optimizing this innovative approach.

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2. Methods

2.1. Participants

Nine participants (Table 1), aged between 68 and 93 years (8 women; *mean age* = 84.55, *SD* = 8.15), were recruited at the Day Care Centre De Rodolfi, in Vigevano, Italy. These individuals presented various cognitive profiles, ranging from mild to moderate dementia.

Inclusion criteria included being 65 years or older, having a diagnosis or probable diagnosis of dementia (documented in medical records), and possessing the capacity for verbal communication and comprehension. Exclusion criteria ruled out those diagnosed with Alzheimer's disease and individuals with other medical or neurological comorbidities. One participant was excluded for not meeting these criteria.

The study was conducted in accordance with the ethical standards of the local Ethics Committee of the Università Cattolica del Sacro Cuore (CERPS; ethical approval received on 08/05/2024, reference number 89/24). Written consent was obtained from the participants or from their relatives in cases where the patients scored below 23 on the Mini-Mental State Examination.

2.2. Measures

Semi-structured interviews explored participants' perceptions, concerns, motivations, and expectations regarding interactions with Pepper. These face-to-face interviews took place in a private room at the Daycare Center, and strategies, such as brief and direct questions, were used to accommodate patients' cognitive impairment (Lloyd, Gatherer, and Kalsy, 2006). The interviews were audio recorded.

Neuropsychological assessments included Addenbrooke's Cognitive Examination - Revised (ACE-R; Pigliautile et al., 2012), which evaluated attention, memory, language, and visuospatial skills, and Mini-Mental State Examination (MMSE; Magni et al., 1996), whose scores were collected by the geriatrician of the Daycare Center between April and June 2024.

2.3. Procedure of training program

The training program took place twice a week for four weeks in July 2024, alternating between cognitive and socio-cognitive sessions. Each session, lasting 20–25 min, was carefully structured, with Pepper providing verbal instructions, feedback, and visual support through its tablet. Two researchers supervised the sessions, which were audio- and video-recorded.

The following training aims to systematize interaction between humans and robots through rigorously designed sessions that present content validated in the literature (Cattelani and Corsini, 2012; D'Arma et al., 2023; Irving et al., 1970; Wilson, 1987; Wilson et al., 2009). At the same time, the sessions are carefully structured to ensure that interactions between humans and the robot are both plausible and engaging. The cognitive training focused on enhancing memory and attentional-executive functions through tasks, such as text and image recall (Cattelani and Corsini, 2012; Irving et al., 1970; Wilson, 1987; Wilson et al., 2009). The socio-cognitive training, inspired by a previous study (D'Arma et al., 2023), focused on ToM, emotional intelligence, and social competence. Pepper served as the primary storyteller, guiding participants through the narratives. The robot took on the role of learner, prompting participants to offer assistance. All questions and feedback were carefully designed to encourage reflection and active engagement. By posing targeted questions and providing constructive feedback, the robot facilitated a dynamic and reciprocal interaction that allowed participants to see themselves as knowledge holders, thereby enhancing their motivation. The researcher assumed the role of facilitator, providing supplementary guidance in the event of incomplete comprehension of instructions or difficulties (Fig. 1).

Table 1
Participants characteristics.

	Mean (n = 9)
Age *(Mean, SD)*	84.55 (8.15)
Cognitive function	*Mean (range)*
MMSE score	17.63 (13–27.2)
ACE-R Tot.	49.75 (21–77)
ACE-R Orientation	10.5 (3–18)
ACE-R Memory	7.75 (0–20)
ACE-R Fluency	3.62 (0–6)
ACE-R Language	18.5 (11–22)
ACE-R Visual-spatial	9.37 (5–13)

All scenarios were designed and implemented through the "Robotic Platform for Social Interaction" *(Piattaforma Robotica per l'Interazione Sociale*; PRIS), a web-based tool developed in collaboration with Intesa Sanpaolo's Innovation Center. The PRIS platform facilitates the programming of Pepper, allowing customized interactions, dynamic dialogues, and real-time data collection on participants' performance.

2.4. Data analysis

Two experimenters conducted a qualitative analysis of the interviews and videos using *a priori* coding scheme (Gibbs, 2014) and followed the six-step inductive thematic analysis of Braun and Clarke (2006). This analysis involved viewing and transcribing the audio content of the interviews and training session videos. Initial codes were then generated for (1) how the participants interacted with the robot (e.g., touching it, looking at its face or the tablet, giving it compliments or criticism, etc.), (2) the emotions and the experiences elicited during the interaction, and (3) the frequency and nature of the participants' requests for the experimenter's intervention. The codes were then grouped into broader conceptual themes (Braun and Clarke, 2006).

3. Results

3.1. Overall findings

Three main themes (Table 2) emerged according to the analysis of participants' interviews and videos: (1) participants' behaviors; (2) participants' experiences; and (3) triadic relationship (participant-researcher-robot).

3.2. Theme 1 – participants' behaviors toward Pepper

The human-like features of Pepper, including its eyes and gestures, led participants to perceive Pepper as a relational entity, attributing intelligence and emotions to it. For example, some described Pepper as "very intelligent" and "handsome," while others projected human-like qualities and biological needs onto the robot, with one participant

Fig. 1. Participant interacting with Pepper robot.

Table 2
Main themes and codes that emerged from the transcripts of the interviews and the videos of the training sessions.

Themes	Codes
Participants' behaviors toward Pepper	Physical appearance; Mental traits; Touch the robot; Positive attitudes.
Participants' experiences	Positive emotions; Reminiscence; Focus.
Triadic relationship	Frequency; Type of intervention.

suggesting that the robot "ate" while it was charging. Remarks such as "This robot thinks of too many things" and "What a brain!" suggested that the robot was viewed as having its own mind. This perception fostered positive engagement and comfort during interactions, with one participant stating, "Look how he looks at me… he almost seems to understand me!"

Although physical contact with Pepper was rare, with only one participant patting it on its face, patients consistently greeted the robot upon entering the room and thanked it at the end of each session, highlighting the emotional connection they felt. See Table 3 for more examples.

3.3. Theme 2 - participants' experiences

The emotions most often elicited by Pepper were joy and surprise, especially when the robot provided positive feedback or addressed participants by name. This was evident during interactions with Pepper where participants frequently exhibited laughter and smiles. Pepper's non-judgmental feedback created a relaxed atmosphere where patients felt comfortable making mistakes. See Table 4 for more examples. This interactive, personalized approach boosted participants' confidence, with many expressing satisfaction and happiness after sessions. In one notable case, a participant was emotionally moved, suggesting that Pepper's meaningful interactions sometimes evoke deeper emotional responses beyond joy and surprise.

As reported in Table 5, Pepper evoked memories and triggered reminiscences in the participants, as seen when they shared personal stories during interactions with the robot. These interactions suggest that Pepper can encourage the recall of past events, promoting a sense of connection and nostalgia. However, the involvement of a therapist is necessary to facilitate and monitor this process.

The structured training helped to focus and attract attention, as evidenced by the case of a patient who often told stories about her son who worked in a local hospital. In human-human interactions, keeping her concentration was challenging as she often wandered off into her narratives. However, during the sessions with the robot, whenever the patient began to lose focus, Pepper would seamlessly continue the training, effectively redirecting her attention back to the task. The interactive nature of the proposed training provided a structured environment that encouraged the patient to remain focused, demonstrating Pepper's effectiveness in supporting engagement.

3.4. Theme 3 – the triadic relationship between participant, researcher, and Pepper robot

The structured protocol facilitated a clear triadic relationship between the patient, the researcher, and Pepper. The robot acted as a mediator, guiding patients through tasks and exercises while the researcher provided support as needed. In each session, participants answered independently, and Pepper provided immediate feedback, offering encouragement for a correct response and repeating the question after an incorrect one. In response to an interview question, all participants indicated that, if necessary, they would turn to the researcher—not the robot—for assistance. In line with this, when patients struggled after a second attempt, Pepper prompted the researcher to intervene, ensuring a balance between patient autonomy and guided support. Over time, participants showed increased attention to Pepper, smiling, nodding, and looking at the robot's face. The researcher's main role was to paraphrase questions and explain how to interact with the tablet while also becoming more independent in using the tablet and engaging with the exercises.

4. Discussion

The interviews and video analysis revealed three main themes that are named as (1) participants' behaviors toward Pepper; (2) participants' experiences; and (3) triadic relationship. The first theme includes behaviors such as touch, attributing mental traits, and positive and negative verbal responses. The second category of codes was used to categorize the emotions and experiences that the participants had during their interactions with the robots. The final category documented the frequency and nature of the participants' requests for the experimenter's intervention.

In line with previous literature, Pepper was well accepted by participants (Manca et al., 2021). Pepper's anthropomorphic features led participants to attribute human-like qualities to it, fostering emotional engagement, laughter, and smiles. One possible reason for mood improvement appeared to bring back people's memories of the time they spent with their familiar care. Other studies have indicated that the use of robots has the potential to evoke previous memories and have discussed the benefits of reminiscence (Birks et al., 2016; Moyle, et al., 2016; 2017).

The robot's structured feedback system helped maintain focus, redirect attention, and create a supportive environment. Its continuous flow of interaction and verbal prompts enabled participants to redirect their attention back to the task. Throughout the sessions, participants became more autonomous in using the tablet to respond to questions. Initially, the researcher's mediation was essential to paraphrase questions and provide directions, but over time, participants became more autonomous. Pepper's feedback system – where it repeated questions after wrong answers and asked the therapist to intervene after two mistakes – helped to scaffold learning and create a safe environment for trial and error. By the later sessions, patients showed increased confidence, interacting more directly with Pepper. This improvement indicates that Pepper's consistent feedback and patient-centered interaction fostered a gradual increase in independence.

Our data, in line with the literature (Talassi et al., 2007), suggest that the use of structured training is more effective in supporting cognitive and socio-cognitive function among elderly participants. As highlighted

Table 3
Participants' beliefs about the Pepper robot as revealed by the interviews and training sessions.

I must thank you [Pepper] because you are good! Very pretty, good, and intelligent. (OBBS03G5L – MMSE 13)
Are you putting him in charge? Ah, you see, he must eat too… (XCC56BTYJ – MMSE 25)
Is there a tape inside to make him talk? (WKH6USUAH – MMSE24)
It was exciting to talk to him. Look how he looks at me… he almost seems to understand me! (ZDDRWLAUI – MMSE 15)
This robot thinks of too many things (UZZHCP8HF – MMSE 17)

Table 4
Emotions experienced by participants when interacting with Pepper.

I tried to make him happy, as I am happy! (OBBS03G5L – MMSE 13)
How good! I was amazed by the talking robot. I thought I had done everything wrong, but instead… how cool we are! (377UYUL5E – MMSE 13)
Alright I'm happy, I thank you for keeping me company (UZZHCP8HF – MMSE 17)

Table 5
Participants' memories triggered by Pepper.

Yes, even me, when the children were not at home, I would tidy up and then they would say, 'Mummy, where did you put my toy? or my book…'. And I said, 'the toy is where all the toys are'. (ZDDRWLAUI – MMSE 15)
Something like this happened to me with my nephew. I threw the toy soldiers out and he looked for them. He said, 'where are the toy soldiers, grandma?' but I threw them away because they bothered him. But later he looked for them. (GSSWCO303 – MMSE 15)
When we went to the sea, we didn't take our dinghies. We didn't have them. We brought food and toys for the children. (1LL4RY8TC – MMSE 17)

in the systematic review by Figliano et al. (2023), existing interventions aimed at slowing cognitive decline in elderly patients are often unstructured, lacking the consistency and precision necessary for long-term effectiveness. To address these limitations, we developed a structured intervention program that includes validated training protocols, measurable outcomes, personalized strategies, and systematic feedback. This approach proved beneficial in enhancing engagement and adherence, with the broader aim of slowing cognitive and socio-cognitive decline in aging individuals, which will be the subject of a future study.

5. Conclusion and limitations

Overall, the present study suggested that the participants accepted Pepper well, and the structured training helped to maintain their attention, improve their autonomy, and create a positive and emotionally supportive environment. Positive feedback from Pepper worked well, especially when tailored to the individual (e.g., mentioning the name of the participant). This kind of feedback was identified as a key factor influencing interaction engagement. The triadic relationship between the patient, researcher, and Pepper proved to be essential in balancing guidance and independence, potentially reducing the therapist burden while enhancing the therapeutic relationship. The Pepper structured feedback system and patient-centered interaction show promise in contributing to both socio-cognitive stimulation and emotional well-being.

Although this preliminary study shows promising results, some limitations must be acknowledged. The study was conducted with a relatively small and heterogeneous sample, limiting the generalizability of the results. Indeed, the current findings were collected from a group of individuals with diverse cognitive profiles, ranging from mild to moderate dementia, introducing variability that may affect the consistency of the results. A larger and more homogeneous sample would enable more representative conclusions about the target populations. Despite this, the eight participants provided relevant data to the study aim, that is, the fine-tuning of the protocol and the need for further refinement of interactions with Pepper to better accommodate individual needs and cognitive capacities. Furthermore, the training program was relatively short, which limits the ability to fully evaluate the long-term effects of using structured training programs. Extending the duration of these interventions would provide a more comprehensive understanding of how repeated and prolonged exposure to training sessions with Pepper could affect cognitive and socio-cognitive outcomes over time. To achieve this objective, additional quantitative measures, such as standardized neuropsychological tests and socio-cognitive tasks, are required. This approach will allow to demonstrate in the future the effectiveness (or lack of it) of the structured training program in improving cognitive and socio-cognitive functions, including memory, executive function and mentalization ability. This prospectively could enhance the reliability of the study.

It can thus be concluded that Pepper and the interventions it delivers were positively received by participants, who showed positive emotions and successful socio-relational involvement. However, the efficacy of these training programs in enhancing or maintaining the cognitive and socio-cognitive functions of the elderly experiencing a decline in these domains remains to be investigated in more depth.

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Declaration of Competing Interest

The authors declared that there is no conflict of interest.

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